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Water Docket

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1200 Pennsylvania Avenue, NW

Washington, DC 20460

On-Line Submission to www.regulations.gov

Department of Commerce and Recreation

Commonwealth of Virginia

203 Governor Street

Richmond, VA 23219

Reference: Virginia Chesapeake Bay Watershed Implementation Plan

Email Submission to: vabaytmdl@dcr.virginia.gov

To Whom It May Concern:

We appreciate the opportunity to submit these comments on the Draft Chesapeake Bay Total Maximum Daily Load document prepared by the U.S. Environmental Protection Agency, and dated 24 September, 2010. Our comments relate specifically to the issue of nitrogen management at the Upper Occoquan Service Authority (UOSA) Water Reclamation Facility (WRF) located in Centreville, Virginia and discharging to the Occoquan Watershed.

Standing for Commentary

The Occoquan Watershed Monitoring Subcommittee (OWMS), and the Occoquan Watershed Monitoring Program (OWMP), are charged under the provisions of the *Occoquan Policy* (VR 680-11-05) with maintaining a continuous record of water quality in the Occoquan Watershed and Reservoir, and reporting to DEQ any changes in water quality due to either point source discharges or nonpoint sources. The purpose of the *Occoquan Policy* is to ensure the preservation of the Occoquan Reservoir as a reliable drinking water supply for the Fairfax County Water Authority (now Fairfax Water), which currently serves a population of over 1.5 million in the Northern Virginia region. We are, respectively, the Chairman of the OWMS, and the Director of the OWMP, capacities in

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which we have served since 1972 and 1975, respectively. From this perspective, we have reviewed the Draft TMDL document with a view to determining if there are any issues with respect to maintaining acceptable raw water quality in the Occoquan Reservoir drinking water supply. While not directly within the field of responsibility of the OWMP, we have also reviewed the draft with respect to likely impacts on nutrient loads delivered to the Potomac Estuary (and thence to the Chesapeake Bay) from the Occoquan Watershed.

In careers totaling over eight decades in Virginia, we have both worked (and continue to work) on issues fundamentally related to restoration of the Bay. Professor Randall was appointed to the inaugural Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program by the Governor of Virginia in 1984, for service beginning in 1985, and served on STAC for 21 consecutive years, including four years as the first Committee-elected chair. He has also conducted fundamental research and extensive implementation of biological processes for the removal of nutrients from wastewater, and the fruits of his efforts may be seen throughout the Bay Watershed. Professor Grizzard has also served as a member of STAC, and has conducted basic research on the transport of nutrients in stormwater, and on the interactions of nutrients between the water column and sediments of impounded waters, efforts of obvious concern for the Occoquan Program, as well as the Bay restoration efforts.

With our respective responsibilities and professional backgrounds, we are writing to voice an urgent concern relative to the application of the backstop provision (as described in Chapter 8 of the TMDL draft) for the total nitrogen load allocation to the UOSA WRF.

Background

The draft TMDL backstop provision assigns an annual UOSA WRF nitrogen load allocation of 657,841 pounds, which is a 50% reduction from the currently permitted 1,315,682 pounds. The latter figure itself represents an annual load limitation that was developed only recently for the UOSA facility (2005), and was based on an 8 mg/L total nitrogen (TN) limit at a discharge flow of 54 million gallons per day (mgd). At the time that load limit was being considered, the OWMS voiced strong concerns about the likely detrimental effects on water quality in the Occoquan Reservoir (Attachment A) if such stringent nitrogen limits were imposed on the UOSA facility. As will be explained herein, the concern was that nitrates discharged by the UOSA WRF serve to maintain current water quality conditions in the Occoquan Reservoir, and that reductions of those loads could be expected to have negative impacts on water quality.

Since 2005, the observed data in the reservoir have only served to strengthen the conclusion that the imposition of that technology-based limit was ill-advised, and that the further reductions proposed in the draft TMDL are likely to have the unintended consequence of contributing to water quality degradation in the Occoquan Reservoir. Indeed, there is an increased risk that application of the backstop nitrogen removal

provision to the UOSA WRF will contribute to the accelerated release of decades of stored nitrogen and phosphorus from the sediments of the reservoir, and the possibility that those releases will reach the Potomac Estuary.

We do not make these assertions lightly, because it is clear that dramatic overall reductions in nitrogen delivery to the Chesapeake Bay are required to implement the TMDL, and that high performance removals from most wastewater treatment facilities are indicated. However, the body of evidence developed from intensive study in the Occoquan Watershed for many years clearly shows that watershed nitrogen management must be viewed from an overall system perspective, and not simply as an end-of-pipe limit imposed at the water reclamation facility. In short, nitrogen loads discharged from the UOSA WRF should not be assumed to be transported conservatively through the reservoir and into the Potomac Estuary. Instead, the UOSA WRF, the Occoquan Watershed and the Reservoir should be viewed as a single nitrogen management system with the release at the Occoquan High Dam as the point for evaluating of nitrogen limits (as is currently stated in the *Occoquan Policy*).

The well-documented biochemical interactions that occur in the impoundment dramatically impact the speciation and concentrations of nitrogen exiting the Occoquan Reservoir. Most of the nitrogen in the UOSA reclaimed water discharge has historically been in the form of nitrate. Much of that nitrate-laden discharge is directed into the bottom waters of the reservoir in the Bull Run arm during the period of thermal stratification. During the attendant period of anoxia, the nitrate serves as an alternate electron acceptor for heterotrophic metabolism – in exactly the same way that it does in biological nitrogen removal from wastewater. The result is that the denitrification reactions *poise* the oxidation-reduction potential (ORP) at a level that is more representative of an oxidizing environment, even in the absence of molecular oxygen. As a result, there is irrefutable evidence that the presence of nitrate prevents or delays the onset of truly anaerobic conditions, and in so doing, dramatically reduces the release of iron, phosphorus, and ammonium nitrogen from the deposited sediments. There is also emerging evidence that the presence of nitrate plays a similar role in reducing the release of manganese, which is also of concern with respect to the quality of the drinking water supply.

In addition to the ORP-driven benefits of the nitrate inputs to the reservoir, the data record also clearly shows that high performance removal of phosphorus at UOSA, coupled with a nitrified reclaimed water discharge, has been instrumental in the maintenance of a phosphorus-limited condition in the reservoir with respect to algal production. The Occoquan Reservoir, it should be noted, is eutrophic – due to the long history of fertilization from all watershed sources (old wastewater discharges, agricultural runoff, and urban stormwater), and was subject to nuisance blooms of *cyanobacter* (blue-green algae) for much of its life. The nitrified discharge from UOSA has been instrumental in creating a high N:P ratio in the impoundment. This, in turn, has been instrumental in selecting for less problematic species of algae (green algae

and diatoms), and has had a beneficial effect in reducing the prevalence of blue-greens. The reduction of *cyanobacter* dominance has been very beneficial from the perspective of water supply operations, given the well-known problems associated with these genera with respect to forming floating mats, creating taste and odor episodes, and secreting undesirable metabolites, including some of known toxicity.

The 2005 Assessment of Nitrate Effects on Water Quality

During the 2005 consideration of changes to the UOSA nitrogen management strategy, the local governments of the Occoquan Watershed, as well as UOSA and Fairfax Water (FW), requested that OWMP staff conduct an assessment of the issues with respect to Occoquan Reservoir water quality. That document, *An Assessment of the Water Quality Impacts of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir*, was made available to the Virginia DEQ and other watershed stakeholders. It is our understanding that a copy of the study has been placed in the current TMDL public comment record by UOSA, and in the interest of space it is not included herein. A key observation of that study was that undesirable water quality conditions were observed to occur in the deep waters of the Occoquan Reservoir during periods of nitrate deficiency. At this point, there is an emerging consensus that nitrate deficiency results when the concentration declines below 2 – 3 mg/L as N, and continuing work is being conducted at OWML to refine this value.

Recent Water Quality Observations

Having enumerated some of the benefits of the presence of nitrate in the Occoquan Reservoir, we would like to provide an illustration of the consequences of *in situ* nitrate deficiency. The figure contained in Attachment B is a 2004 – 2009 time series of watershed rainfall and the ammonium, oxidized nitrogen, and total phosphorus concentrations in the deep waters of the Occoquan Reservoir upstream of the Occoquan Dam. This sampling station (RE02) is generally visited by OWMP staff on a weekly basis, except during the winter months, when the sampling frequency is reduced to bi-weekly. Also shown on the plot are annual total nitrogen loads from UOSA.

In examining the figure, it should also be noted that, in addition to denitrification, nitrate concentrations in the Reservoir are reduced under two other principal scenarios (or combinations thereof): (1) lower loads delivered from the UOSA WRF, or (2) short-term dilution from high flow events in the summer months.

Over the last 2+ years, UOSA has been gaining operational experience with its nitrogen removal capabilities, with the result that the nitrate load delivered to the Occoquan Reservoir has been significantly reduced for certain periods. Over that period of time, we have closely observed the attendant water quality effects.

In examining the plotted time series data, it may be seen that even in years where the nitrate load from USOA was higher than the new permit limit of 1.3 million pounds, periods of deficiency occurred. However, during those periods, the release of

ammonium nitrogen and phosphorus from the reservoir sediments was for relatively short durations, and generally resulted in lower peak concentrations. Periods when nitrate discharges from UOSA were inadequate to maintain a protective concentration in the deep waters were consistently accompanied by dramatic increases in the release of ammonium nitrogen and phosphorus from the sediments. Some specific comments on the conditions for years illustrated in the plot follow:

- **2004** - During 2004, UOSA discharged 1.2 million pounds of nitrogen, and the peak concentrations of nitrate were slightly less than 2 mg/L as N. However, there were no observed periods of nitrate depletion. The peak ammonium-N and total phosphorus (TP) concentrations were 1.3 and 0.07 mg/L, respectively. The summer of 2004 was also characterized by the relative absence of high flow events that might have disturbed the stratification and/or diluted the nitrate concentrations. This period is a good illustration of the condition where nitrate is being removed in the reservoir, and also serving to control ammonium and phosphorus release.
- **2005** - During 2005, UOSA discharged 1.7 million pounds of nitrogen, and the peak summer concentrations of nitrate ranged from approximately 1 – 3 mg/L as N. There was a short period of near-depletion of nitrate in July, which was exacerbated by a high flow event. The absence of nitrate was accompanied by a peak ammonium-N concentration of 2.4 mg/L, and TP slightly above 0.1 mg/L.
- **2006** - Although UOSA discharged 1.6 million pounds of nitrogen in 2006, very high summer streamflows effectively diluted the concentrations in the reservoir, with the result that nitrate was completely depleted by early July, and did not recover until the loss of stratification in October. This resulted in an extended period in which the ammonia-N concentrations released from the sediments greatly exceeded the nitrate-N concentrations, and actually reached peak values in excess of 5 mg/L. During the same period of nitrate deficiency, the peak TP concentrations exceeded 0.6 mg/L.
- **2007** – During 2007, UOSA reduced its TN load from the prior year by 700,000 pounds. Because there were also no large rain events that flushed the Reservoir and diluted the nitrate concentrations, 2007 represented an excellent year to assess the impacts of reduced nitrate inputs. During that year, the highest deep water concentration of nitrate observed was approximately 3.5 mg/L as N, and occurred early in the year. By early March, the concentration had declined below 1 mg/L, and was effectively zero for most of the summer. The peak ammonium-N concentration reached after the depletion of nitrate was, by contrast, nearly 5 mg/L. In the same period, a peak TP concentration of over 1

mg/L was observed (much of it soluble). The concentrations of both these nutrients remained high in the deep water until the fall circulation, which did not occur until early November.

- **2008** - In 2008, the UOSA nitrate load was similar to that delivered in 2007. However, prior to the establishment of the thermal stratification, large flows were experienced that effectively diluted the *in situ* nitrate-N concentration to well under 1 mg/L. As a result, peak ammonium-N concentrations in excess of 3 mg/L were observed.
- **2009** – The situation in 2009 was not unlike that experienced in 2008, with relatively high rainfall in May and June. Nitrate-N was effectively depleted by early June, and the resulting ammonium-N concentrations remained in the 2 – 4.5 mg/L range for most of the summer.

The ammonium and phosphorus releases described above are well-known consequences of the establishment of anaerobic conditions in deep eutrophic lakes and reservoirs during the period of thermal stratification. What is consistently of note in this system, however, is that the releases may clearly be seen to be tempered in large part by the presence of nitrate. In its role as an alternate terminal electron acceptor (TEA) in anoxic respiration, nitrate has the effect of poisoning the oxidation-reduction potential at a level that significantly reduces the release of phosphorus and ammonium from the sediments. At the same time, also in its role as a TEA, nitrate is largely converted (reduced) to nitrogen gas and removed from the system. This too has been observed in the Occoquan Reservoir for many years.

Summary

The complete body of water quality evidence on the Occoquan Watershed-Reservoir system offers a compelling picture of the importance of examining the *system*, and not just its component parts, when crafting a water quality management strategy. The assumption that applying the backstop nitrogen removal requirement to the UOSA WRF discharge will result in a 1:1 reduction in nitrogen delivery to the Chesapeake Bay is fundamentally flawed. In fact, imposing the limit may have the unintended consequence of actually increasing the phosphorus and nitrogen loads exiting the Occoquan Reservoir, and at the same time further degrading water quality in a critically needed drinking water supply. The previously-cited 2005 report from OWML (*An Assessment of the Water Quality Impacts of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir*) reached similar conclusions. Upon its review of that document, the Occoquan Watershed Monitoring Subcommittee unanimously accepted the report recommendations, and directed the chairman to communicate those findings to the Virginia DEQ. That letter (previously cited as Attachment A) contained the following recommendation:

“...it is the conclusion of the OWMS that implementation of the proposed [technology-based] nitrogen reductions for UOSA would be detrimental to water quality in the Occoquan Reservoir, and would needlessly threaten the public health of the more than 1.2 million FW [Fairfax Water] customers who rely on the Reservoir for drinking water. Therefore, the OWMS, by unanimous vote, recommends that the new nitrogen reduction requirements not be imposed on the UOSA WRF at this time, and that the current nitrogen management strategy of the *Occoquan Policy* remain in force pending the completion of needed research by OWML.”

We should point out at this time, that the above-referenced recommendations of the OWMS were that **no** reductions in nitrate in the UOSA discharge would be undertaken unless necessitated by the requirement to maintain a raw water intake concentration of no more than 5 mg/L as N. In 2007, and contrary to recommendations of the OWML assessment and the OWMS, the Virginia DEQ imposed the current annual total N load cap of approximately 1.3 million pounds.

Even though this decision was taken 3 years ago, we have continued to think it was an unwise approach to managing the system, and the current backstop nitrogen removal proposal has certainly elevated our level of concern about unintended consequences. Our concerns were specifically highlighted in our letter to Virginia DEQ on 25 May, 2007 (Attachment C) regarding the 1.3 million pound permit limit. Professor Grizzard continued to voice our misgivings about consideration of further lowering the UOSA load allocation in an opinion delivered to UOSA in a letter dated 14 September, 2009 (Attachment D).

Now, as then, we strongly caution against the application of new nitrogen load reductions to the UOSA WRF, particularly at this point in time. The risks of undesirable outcomes with respect to local water quality are simply too great, as are the risks of not achieving the anticipated results for the Chesapeake Bay. A far more rational approach to nitrogen management in the Occoquan Watershed would be to continue to build on the base of the water quality studies and modeling work currently underway so that further refinements in a management strategy may be developed in a way that carries a lower risk of triggering unacceptable water quality outcomes.

We are appreciative of the opportunity to voice our opposition to the current backstop proposal, and we hope that a careful review of our concerns will be conducted. Because of the foresight of regulatory agencies in the Commonwealth of Virginia and other watershed stakeholders, extending back over four decades, we are in a unique position to make careful and supportable management decisions in the Occoquan Watershed. In our judgment, it would be unwise to proceed with new decisions that are not similarly well-grounded on the scientific understanding that has been developed in this critical Northern Virginia water resource.

We hope that these comments have provided some additional insights into the issues at hand in considering the draft TMDL. If you would like to discuss the data further, or would like to have more input on our concerns, please contact either of us at your convenience.

Sincerely,



Clifford W. Randall, Ph.D.
The Charles Lunsford Professor Emeritus
Chairman, Occoquan Watershed
Monitoring Subcommittee



Thomas J. Grizzard, P.E., Ph.D.
Professor of Environmental Engineering
Director, Occoquan Watershed Laboratory

TJG:CWR:msw

Attachments

Attachment A

Letter from Clifford W. Randall to Virginia DEQ
Dated: 15 June, 2005

Dr. Clifford W. Randall
Environmental Engineering Program
418 Durham Hall
Blacksburg, Virginia 24061-0246
(540) 231-6018 Fax: (540) 231-7916

June 15, 2005

Carol C. Wampler, Chairman
Virginia State Water Control Board
4262 Byrd Lodge Road
Richmond, Virginia 24141

RE: Proposed Changes to UOSA Permit related to nitrogen removal

Dear Chairman Wampler:

The Occoquan Watershed Monitoring Subcommittee (OWMS) of the Virginia State Water Control Board (VSWCB) met on June 9th, 2005 to review the water quality protection activities of the Occoquan Program, and the implications of proposed changes in the discharge permit for the Upper Occoquan Sewage Authority (UOSA) Water Reclamation Facility (WRF). These changes, which would be required under new regulations being considered by the VSWCB, would mandate that the UOSA WRF reduce its discharge nitrogen from the current level of 20 - 25 mg/L to less than 8 mg/L as soon as possible, and then to less than 3 mg/L when the next expansion occurs.

As you know, the primary responsibility of the OWMS is to ensure that the water quality of the Occoquan Reservoir is preserved and protected so that it will continue to be a reliable source of drinking water for the more than 1 million citizens of Northern Virginia served by Fairfax Water (FW). However, you may not be aware that the highly nitrified discharge from the UOSA WRF has been found by the Occoquan Program, which the OWMS oversees on behalf of the Board, to play a key role in the protection of Occoquan Reservoir water quality. Since 1978, the nitrates in the UOSA discharge have served to prevent or delay the onset of anaerobic conditions in the Reservoir sediments, and thus prevent or delay the release of both phosphorus and ammonia nitrogen back to the Reservoir water column. Control of these sediment nutrient sources has served to reduce the supply available to algae and has been an important component of the overall improvement of Reservoir water quality in the post-UOSA years. The effectiveness of the nitrates for the prevention or delay of detrimental conditions is directly related to the quantity of nitrate contained in the WRF discharge, and a reduction of the amounts currently being discharged will almost certainly have undesirable water quality impacts. There are indications, for example, that removal of nitrates from the Reservoir might actually result in a net increase in nitrogen and phosphorus loads exiting the Reservoir and entering the Potomac Estuary.

It should also be noted that much of the nitrate from the WRF is already removed by denitrification processes as it passes through the Reservoir. Thus, an overall reduction in nitrogen loads entering the Potomac Estuary is accomplished by the same processes that protect Reservoir water quality.

The importance of the nitrates in the UOSA discharge for the control of sediment phosphorus and ammonium release, the control of algal growth in the Occoquan Reservoir, and the detrimental effects that are likely to result if the WRF nitrates are reduced in accordance with the proposed regulation(s), have been detailed in a report entitled, "An Assessment of the Water Quality Effects of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir." The report was prepared by the staff of the Occoquan Watershed Monitoring Laboratory (OWML) at my request, and a copy accompanies this letter.

Following review of the report, it is the conclusion of the OWMS that implementation of the proposed nitrogen reductions for UOSA would be detrimental to water quality in the Occoquan Reservoir, and would needlessly threaten the public health of the more than 1.2 million FW customers who rely on the Reservoir for drinking water. Therefore, the OWMS, by unanimous vote, recommends that the new nitrogen reduction requirements not be imposed on the UOSA WRF at this time, and that the current nitrogen management strategy of the *Occoquan Policy* remain in force pending the completion of needed research by OWML.

It is anticipated that it will take approximately two years to perform the necessary *in situ* and microcosm research, correlate the results with observed Monitoring Program data, and perform computer modeling to determine the nitrate concentrations in the WRF discharge that will be protective of Reservoir water quality. It should be noted, however, that modeling based on existing OWML monitoring data strongly indicates that a reduction of nitrates in the current WRF discharge would be detrimental to Reservoir water quality, based on typical Reservoir water volumes and flows.

If you would like to discuss the report, or if you have any questions, please contact me at your convenience. Dr. Grizzard, who is the Director of OWML, and I would also be happy to meet with you in person.

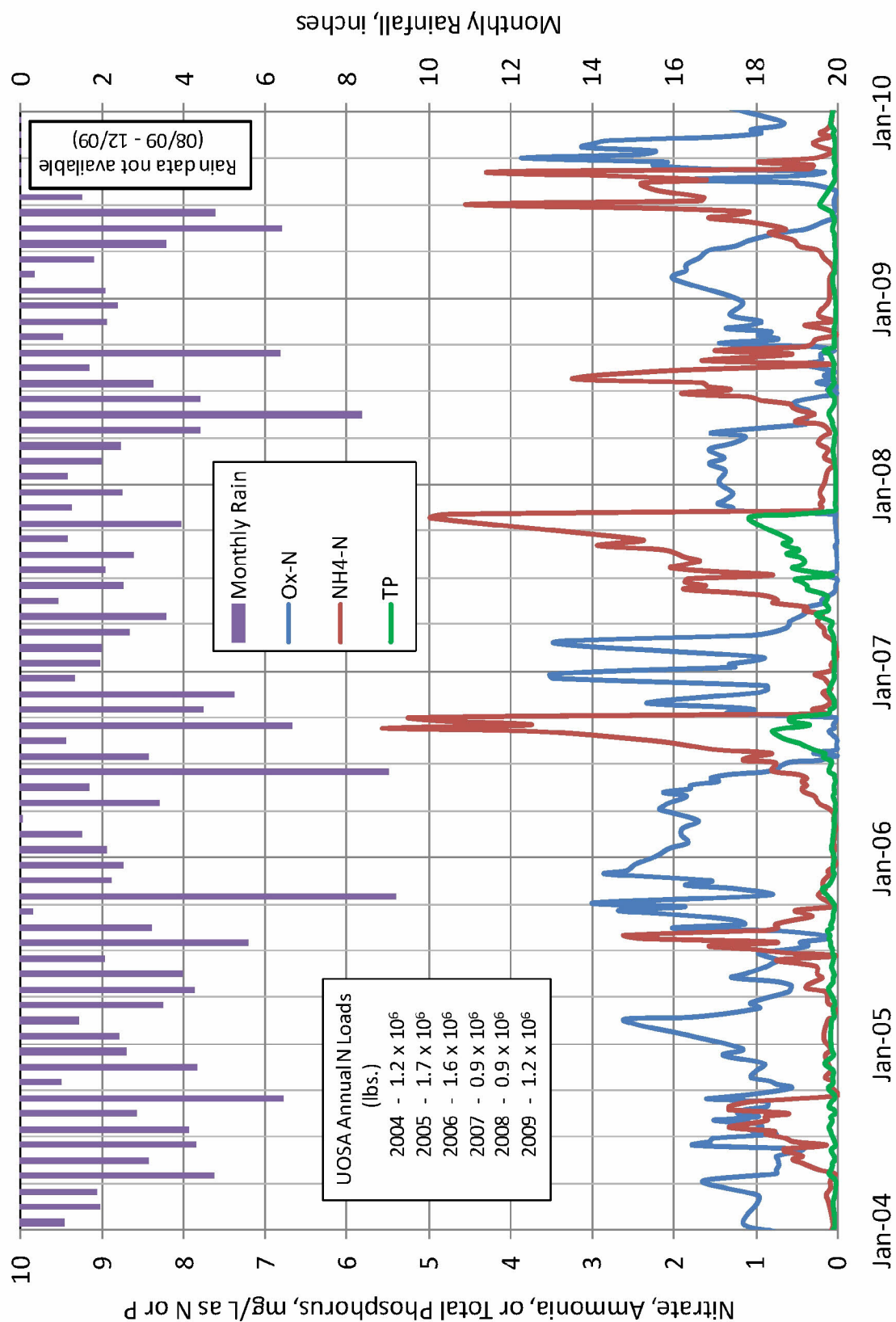
Yours truly,

Clifford W. Randall, PhD
Chairman, Occoquan Watershed Monitoring Subcommittee

Copies: R. Burnley, A. Pollock, J. Kennedy
Enclosure

Attachment B

Time Series Plot of Rainfall and Nutrient Concentrations
in the
Occoquan Reservoir near the Occoquan High Dam, 2004 – 2009



Attachment C

Letter from Clifford W. Randall and Thomas J. Grizzard
To Alison Thompson, Virginia DEQ
Dated: 25 May, 2007

25 May, 2007

Ms. Alison Thompson
Water Permit Writer
Virginia Department of Environmental Quality
Northern Virginia Regional Office
13901 Crown Court
Woodbridge VA 22193

Dear Ms. Thompson:

As you know, the Occoquan Watershed Monitoring Program (OWMP) is charged, under the provisions of the *Occoquan Policy* (VR 680-11-05), with maintaining a continuous record of water quality in the Occoquan Watershed and Reservoir, and reporting to DEQ any changes in water quality due to either point source discharges or nonpoint sources.

Because of that responsibility, we are writing to express our concern that some unintended, but serious, water quality consequences may result from the application of a recently-revised DEQ regulation to an upcoming renewal of the VPDES Permit for the Upper Occoquan Sewage Authority (UOSA) Water Reclamation Facility. Specifically, we are referring to 9VAC-25-40-70 (*Strategy for the Chesapeake Bay Watershed*), under which a plant owner who, "expands his facility to discharge...500,000 gallons or more per day, or an equivalent load, directly into nontidal waters shall install state-of-the-art nutrient removal technology at the time of the expansion and achieve an annual average total nitrogen effluent concentration of 3.0 milligrams per liter..."

This regulation modification has resulted from a continuing effort by the Commonwealth to fully participate in the national and regional commitment to restore water quality in the Chesapeake Bay. The new regulation also follows (and could supersede) a 2005 UOSA permit modification that applied an annual cap load of 1,315,682 pounds of nitrogen. The annual load limitation was computed at a concentration of 8 mg/L as N on a discharge flow of 54 mgd. From the standpoint of the concerns we will expand on later in this letter, it should also be noted that the computed cap load is very close to the actual annual nitrogen discharges from the UOSA WRF at present flows and full nitrification.

2005 Water Quality Assessment

During late 2004 and early 2005, numerous discussions were held between stakeholders in the Occoquan Watershed on the topic of Chesapeake Bay regulation effects on UOSA discharge permit limits. Participants included DEQ, the key public

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service authorities of Fairfax Water (FW) and UOSA, representatives of watershed jurisdictions, and OWMP staff. During that time, the UOSA Board of Directors, and representatives of local governments in the Occoquan Watershed requested that OWMP provide a technical analysis of the nitrogen issues and the impacts on potential permit limits, particularly as they related to water quality in the Occoquan Reservoir. Specifically, OWMP staff were requested to:

- Conduct an evaluation of existing data regarding the impacts of the UOSA WRF discharge on the Occoquan Reservoir, particularly as it relates to nitrogen management and any attendant effects on water quality;
- Provide an assessment of the possible water quality risks of altering current UOSA WRF operations to conform with the nitrogen management strategy being proposed by DEQ;
- Identify information deficiencies, and to recommend additional studies that will be necessary to remedy those deficiencies.

In April, 2005, OWMP staff completed a detailed analysis of the technical issues, which was entitled, *An Assessment of the Water Quality Effects of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir*. The report (copy attached) found, among other things that:

- "The available data and the analysis presented... contribute to a compelling picture of the importance of the nitrified discharge from the UOSA WRF in the maintenance of existing water quality conditions in the Occoquan Reservoir"
- "The data also suggest that there are risks associated with the removal of nitrogen from the UOSA WRF discharge without fully understanding the local water quality impacts."

The report also recommended that, "Given the long history of improved Occoquan Reservoir water quality related to the nitrate supply from the UOSA WRF, it would be prudent to defer changes in nitrogen permit limits until the scale of consequences to local water quality and the regional water supply are fully understood."

The report and its conclusions were presented to the Occoquan Watershed Monitoring Subcommittee (OWMS) of the State Water Control Board for consideration on 09 June, 2005. At that meeting, the Subcommittee unanimously endorsed the report and its recommendations, and, further, directed the OWMS Chairman (Dr. C.W. Randall) to communicate this view to the Chairman of the State Water Control Board, along with a

summary of the technical rationale. The substantive recommendation in the letter (copy attached) from Dr. Randall was that:

“...it is the conclusion of the OWMS that implementation of the proposed [technology-based] nitrogen reductions for UOSA would be detrimental to water quality in the Occoquan Reservoir, and would needlessly threaten the public health of the more than 1.2 million FW customers who rely on the Reservoir for drinking water. Therefore, the OWMS, by unanimous vote, recommends that the new nitrogen reduction requirements not be imposed on the UOSA WRF at this time, and that the current nitrogen management strategy of the *Occoquan Policy* remain in force pending the completion of needed research by OWML.”

As a result of the water quality analysis by OWMP staff, and further discussions between DEQ, UOSA, FW, and other watershed stakeholders, it was agreed that only the aforementioned annual cap load for nitrogen would be adopted pending the completion of research identified by OWMP as needed to better define the nitrogen requirements that would be protective of Occoquan Reservoir water quality.

OWMP staff viewed this approach as a prudent means of avoiding unacceptable risks to the raw drinking water supply for much of Northern Virginia, while still providing a sound basis for making progress towards the nutrient limitation goals necessary for Chesapeake Bay restoration.

From the standpoint of avoiding unacceptable degradation of Occoquan Reservoir water quality, the approach recognized that:

- Water quality observations in the reservoir have shown that maintenance of nitrate concentrations of 2 – 4 mg/L (as N) in the bottom waters of the Occoquan Reservoir can be expected to provide protection against the liberation of sediment-bound phosphorus, ammonium, iron, and manganese by maintaining an oxidizing environment during periods of oxygen depletion.
- A (desirable) condition of phosphorus limitation (high N:P ratios) for phytoplankton growth is enhanced by maintaining the nitrate discharge from UOSA. The high N:P ratio helps to select for green algae instead of the more problematic blue-green algae (*Cyanobacter*) in the reservoir.
- The presence of nitrate as the principal nitrogen source for phytoplankton (instead of ammonium) also selects in favor of green algae and diatoms instead of the blue-green algae.

- The net effect of the biochemical processes at work in the system is that nitrate is reduced to nitrogen gas and is removed from the system by loss to the atmosphere. Except in extreme cases of drought, the existing UOSA discharge has been shown to provide sufficient quantities of nitrate to be protective of water quality, and the reservoir has the capacity to remove sufficient quantities of nitrate to prevent concentrations from approaching the drinking water MCL of 10 mg/L as N.

From the standpoint of achieving the nutrient reduction goals for the Chesapeake Bay restoration, the approach recognized that there may be substantial risks associated with the adoption of technology-based nitrogen discharge limits, because:

- The presence of nitrate in the Occoquan Reservoir maintains an oxidizing environment that prevents the release of ammonium and phosphorus into the water column from the deposited sediments. This has the benefit of contributing to the trapping of nitrogen and phosphorus from **all** watershed sources (including nonpoint pollution) in the reservoir sediments, and reducing transport downstream to the Potomac Estuary and ultimately, the Chesapeake Bay.
- The reduction of nitrate during periods of hypolimnetic anoxia, and in near-sediment anoxic microzones during other periods, results in the loss of nitrogen to the atmosphere. This process (dissimilatory denitrification) also removes nitrogen prior to entry into the Potomac Estuary.
- Inflow-outflow monitoring of the reservoir for more than 20 years indicates that substantial net removals of **all** watershed nitrogen takes place in the reservoir as a result of biological uptake, sedimentation, sediment sorption, and denitrification.

Potential Impact of Technology-Based Nitrogen Limits

As has been discussed above, the water quality of the Occoquan Reservoir has benefited substantially from the continuous source of nitrate contained in the UOSA WRF discharge. At its present flows, and nitrogen concentrations of 15-18 mg/L, which enter Bull Run from the WRF Final Effluent Reservoir, UOSA discharges from 1.4 – 1.6 million pounds annually. From the intensive data collection undertaken by OWMP, and described in the 2005 report, we have observed these loads to be protective of reservoir water quality through the mechanisms discussed above.

The uncertainties that currently exist with respect to nitrogen management in the Occoquan Watershed relate principally to the question of how much nitrate is sufficient to obtain and maintain the desired water quality benefits.

From the standpoint of maintaining maximum protection of water quality in the Occoquan Reservoir, we would contend that no reductions in the current nitrate loads from UOSA should be contemplated until the water quality effects can be adequately predicted.

For example, results from simulations using the Occoquan Watershed Computer Model indicate that, at current UOSA flows and full nitrification, substantial periods of nitrate deficiency would be experienced in the reservoir under the range of hydrologic conditions experienced in the model calibration period of 1988 – 1992. It goes without saying that reductions of the loads to values associated with discharge limits of 3 or 8 mg/L as N would result in much longer periods of nitrate deficiency and unnecessarily raise the risk of unacceptable water quality consequences in the Reservoir. At current flows and an annual discharge limit of 3 mg/L as N, for example, nitrate loads delivered to the reservoir would be lower than have been experienced since the UOSA WRF was placed in service in 1978.

In summary, there is strong evidence that the application of technology-based discharge limits for nitrogen in the UOSA reclaimed water discharge may well have the unintended consequence of not only degrading water quality in the Occoquan Reservoir, but also may result in an increase in nutrient loads (both N and P) delivered to the Potomac Estuary, and thence to the Chesapeake Bay.

For this, and all the other reasons set forth herein, it is our strong opinion that only the cap load for nitrogen should be incorporated into the UOSA permit renewal pending the completion of additional water quality studies by the Occoquan Watershed Monitoring Laboratory (OWML).

Ongoing Studies

As was recommended in the 2005 report, *An Assessment of the Water Quality Effects of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir*, OWML staff have been working with representatives of FW and UOSA to fund and complete a comprehensive set of studies designed to more rigorously define the minimum nitrate requirements of the reservoir and the local and downstream water quality risks associated with nitrate removals.

Initial studies are currently underway using continuous flow microcosms to simulate the sediment-water interactions of several chemical species of interest, including nitrogen, phosphorus, iron, and manganese. Recommended work that is still being negotiated includes algal growth limitation and succession studies; *in situ* measurements of nitrate transport in the reservoir; and modifications to the Occoquan Model to include more mechanistic simulations of nutrient interaction and transport in the reservoir.

It is expected that the complete suite of studies will be completed well before the expiration date of the permit currently being negotiated. At that time, we will be in a position to more definitively address the minimum nitrate requirement issue. For the present, however, we continue to hold the view that imposition of a technology-based N concentration limit at UOSA is not justified, and also poses very real water quality risks for the Occoquan Reservoir and Chesapeake Bay.

UOSA Permit Renewal

We hope that this letter has provided adequate information for you to consider in your deliberations on the UOSA VPDES permit renewal. As I understand it, the language contained in 9VAC25-40-70 paragraph A.4 allows DEQ, upon an adequate demonstration of a risk of degrading receiving waters, to assign an annual nitrogen load limit in lieu of a technology-based discharge limit. It is our strongly held view that there could be no better demonstration of this case than in the Occoquan Watershed. Regulating with the previously-computed annual load cap while needed studies are completed represents a prudent approach to protecting both the drinking water supply and the Chesapeake Bay.

We hope that this letter will provide you with the necessary input for your deliberations, but if you would like to further discuss the issue, or if you have any questions, please contact either of us at your convenience.

Sincerely,



Clifford W. Randall, Ph.D.
Lunsford Professor Emeritus
Chairman
Occoquan Watershed Monitoring
Subcommittee



Thomas J. Grizzard, Ph.D., P.E.
Professor of Environmental Engineering
Director
Occoquan Watershed Monitoring
Laboratory

TJG:mo

Copies: Charles Boepple, UOSA
Charles Murray, FW
John Kennedy, DEQ
Members, OVMS

Attachments (2)

Attachment D

Letter from Thomas J. Grizzard
to Charles P. Boepple, UOSA
Dated: 14 September, 2009

14 September, 2009

Mr. Charles P. Boepple, P.E.
Executive Director
Upper Occoquan Service Authority
14631 Compton Road
Centreville, VA 20121-2506

Dear Mr. Boepple:

At your request, I am writing to provide an assessment of the water quality impacts in the Occoquan Reservoir resulting from changes in nitrogen management strategies at the Upper Occoquan Service Authority (UOSA) in the period from 2007-2008.

I understand that the near-term need for this analysis was precipitated by a 12 August, 2009 letter from the Virginia Department of Environmental Quality (VDEQ) requesting that you provide information on the impact of the reduced UOSA nitrogen loads on water quality in the Occoquan Reservoir during that period.

2005 Assessment and Recommendations

As you know, within the constraints of our funding, we have been actively studying this issue for some time. The most recent detailed analysis was contained in a document that I authored and conveyed to the Occoquan Watershed Monitoring Subcommittee (OWMS), UOSA, and VDEQ in the spring of 2005. *An Assessment of the Water Quality Impacts of Nitrate in Reclaimed Water Delivered to the Occoquan Reservoir* contained a detailed review of the historical *in situ* data on nitrate sources, transformations, and removals in the Occoquan Reservoir, as well as summaries of laboratory microcosm experiments that have been conducted at the Occoquan Watershed Monitoring Laboratory (OWML) over many years. The report contained a range of observations and recommendations, among which were the following statements:

“The available data and the analysis presented in this report contribute to a compelling picture of the importance of the nitrified discharge from the UOSA WRF in the maintenance of existing water quality conditions in the Occoquan Reservoir.

The data also suggest that there are risks associated with the removal of nitrogen from the UOSA WRF discharge without fully understanding the local water quality impacts.”

Invent the Future

2005 Occoquan Watershed Monitoring Subcommittee Recommendations

The report and all its recommendations were unanimously adopted by the OWMS at its meeting of 09 June, 2005. Further, the OWMS directed the Chairman, Dr. Clifford W. Randall, to communicate the endorsement and a summary of the technical rationale on which it was based to the chairman of the VSWCB. That letter, dated 15 June, 2005, contained the following recommendation:

“...it is the conclusion of the OWMS that implementation of the proposed [technology-based] nitrogen reductions for UOSA would be detrimental to water quality in the Occoquan Reservoir, and would needlessly threaten the public health of the more than 1.2 million FW [Fairfax Water] customers who rely on the Reservoir for drinking water. Therefore, the OWMS, by unanimous vote, recommends that the new nitrogen reduction requirements not be imposed on the UOSA WRF at this time, and that the current nitrogen management strategy of the *Occoquan Policy* remain in force pending the completion of needed research by OWML.”

I should point out that the recommendations of the OWMS were based on an implicit understanding that **no** reductions in nitrate in the UOSA discharge would be undertaken unless necessitated by the requirement to maintain a raw water intake concentration of 5 mg/L as N.

2007 Nitrogen Cap

In spite of the OWML assessment and the OWMS recommendation, VDEQ nevertheless imposed an annual total N load cap of approximately 1.3 million pounds in 2007. I must say that this decision has always concerned me. I do not make this statement lightly, and it is in no way meant to minimize the importance of the continuing effort to reduce nitrogen loads to the Chesapeake Bay. In two terms of service as an at-large member of the Scientific and Technical Advisory Committee (STAC) to the Bay Program, I have developed a clear understanding and appreciation of the nitrogen management challenges faced by the states and the District of Columbia. However, as I have stated to you many times, regulatory approaches that rely on an end-of-pipe accounting of nitrogen loads may ignore significant transformations in the environment, and may, therefore, be vulnerable to unintended and undesirable consequences. The case of the Occoquan Watershed is, in my judgment, an object lesson on this point.

Recent Reservoir Conditions

In the last 2+ years, UOSA has been gaining operational experience with its nitrogen removal capabilities, and has dramatically decreased the nitrate load delivered to the Occoquan Reservoir. During that period, we have had an opportunity to observe the water quality effects of the load reduction. The 2005 Assessment made the point that undesirable water quality conditions occur in the deep Reservoir waters during periods of nitrate deficiency. At this point, we are developing an internal consensus that nitrate deficiency results when the concentration declines below 2 – 3 mg/L as N. We have

studies underway to refine this value, but for the purposes of this discussion, the stated range should serve to illustrate the point.

The attached figure is a time series of rainfall, ammonium, oxidized nitrogen, and total phosphorus in the deep waters of the Occoquan Reservoir upstream of the Occoquan Dam. This sampling station (RE02) is generally visited by OWML staff on a weekly basis, except during the winter months, when the sampling frequency is reduced to bi-weekly. Also shown on the plot are the annual total nitrogen loads from UOSA from 2004 – 2008.

An examination of the plotted time series data from the same period clearly illustrates the water quality consequences stemming from nitrate deficiency during the mid- to late-summer periods for both 2007 and 2008. Periods when nitrate discharges from UOSA were inadequate to maintain a protective concentration in the deep waters were consistently accompanied by dramatic increases in the release of ammonium nitrogen and phosphorus from the sediments.

The summer of 2007 is perhaps the most representative period in that there were no very large rain events that resulted in flushing of the Reservoir and lowering of the nitrate concentrations by dilution. During that year, the highest deep water concentration of nitrate observed was approximately 3.5 mg/L as N, and occurred early in the year. By early March, the concentration had declined below 1 mg/L, and the concentration was effectively zero for most of the summer. The peak ammonium concentration reached after the depletion of nitrate was, by contrast, nearly 5 mg/L as N. In the same period, a peak total phosphorus concentration of over 1 mg/L was observed (much of it soluble). The concentrations of both these nutrients remained high in the deep water until the fall circulation, which did not occur until early November.

These conditions are well-known consequences of the establishment of anaerobic conditions in deep eutrophic reservoirs during the period of stratification. What is of note in this system, however, is that the releases may be seen to be tempered in large part by the presence of nitrate. In its role as an alternate terminal electron acceptor (TEA) in anoxic respiration, nitrate has the effect of poisoning the oxidation-reduction potential at a level that significantly reduces the release of phosphorus and ammonium from the sediments. Of course, in its role as an alternate TEA, nitrate is largely converted (reduced) to nitrogen gas and removed from the system. This too has been observed in the Occoquan Reservoir for many years.

It should be noted that the increased N and P releases from the sediments may also be observed during periods when the nitrate concentrations were artificially decreased by large storm events entering the system. In fact, a peak ammonium concentration of over 5.5 mg/L as N was observed in September, 2006 following such an event prior to the fall circulation.

Summary and Continuing Work

I think there is an essentially unambiguous interpretation of the water quality data presented for 2007 – 2008: the decreased UOSA nitrate supply had clear and undesirable consequences for local Reservoir water quality. The increased release of stored nitrogen from the Reservoir sediments very likely had additional consequences for loads delivered downstream. We have not yet completed our analysis of the overall nitrogen mass balance for the period, but reference to the attachment shows that peak concentrations of ammonium nitrogen (released from the sediments) exceeded peak nitrate concentrations (largely originating from UOSA) by 42 percent.

As you know, we are continuing to conduct intensive studies of the behavior of nitrate in the reservoir system. During the summer of 2009, with your cooperation, we have been able to study the system response during an extended period of operation of the UOSA WRF in full nitrification mode. The data collection during this period has been substantially enhanced by the purchase of an instrument (funded by UOSA) to measure continuous nitrate concentrations *in situ*. This has made it possible for us to develop detailed longitudinal and vertical profiles of nitrate in the Reservoir for most of 2009. The study is not yet complete, and our detailed analysis has only just begun. However, it is clear that our understanding of denitrification in the Reservoir has been enhanced by the *in situ* measurements. We have, for example, seen that nitrate carried in the flows of Bull Run is preferentially mixed into the deep waters of the Reservoir even during periods of very weak thermal stratification. This is encouraging news from the standpoint of nitrogen removal in the overall system, because the nitrate is consistently directed into the reservoir zones where denitrification is favored.

There are significant questions still to be answered. Some obvious ones are:

- What is the minimum *in situ* nitrate concentration required to maintain optimal water quality conditions in the reservoir deep waters?
- How much additional nitrogen and phosphorus may be exported to the Potomac Estuary as a consequence of Reservoir nitrate deficiency?
- What is the denitrification capacity of the Reservoir under varying flow conditions from UOSA and the Occoquan Watershed, and what is the longitudinal variability of Reservoir denitrification rates?
- How should the timing of nitrate loads be managed to insure an adequate supply is available at the early onset of thermal stratification?
- What are the risks of returning to *cyanobacter*-dominated algal populations if the N:P ratios are reduced from current values?

These are only a few of the important questions to be addressed, and there is much work still to be done. For example, there is a critical need for the development of a robust simulation capacity to help UOSA and FW develop best practices for start-up and shut-down of nitrogen removal. The basic model framework is in place, but extending the system to provide this predictive capability requires substantial enhancements.

I am also grateful for the continuing funding from UOSA that has supported our laboratory microcosm studies, which are making it possible to develop refined estimates of the longitudinal variability of denitrification rates in the Reservoir. These studies are also proving useful in quantifying the effects of nitrate in reducing the release of iron and manganese from the deposited sediments, which is an area of critical interest for the drinking water supply. Our capacity to simulate the entire length of the Reservoir as a cascade of completely mixed reactors is now well-established, and I hope that this capability will continue to reveal new insights into the behavior of the full-scale system.

In summary, I would say that I would strongly caution against the application of new nitrogen load reductions to the UOSA WRF, particularly at this point in time. The risks of undesirable outcomes with respect to local water quality are simply too great. A more rational approach would be to build on the base of the water quality studies and modeling work currently underway. Such a program, developed jointly by UOSA, FW, OWML, and DEQ, and adequately funded, should make it possible to answer the necessary questions in an objective manner. It should then be possible to engage in rational regulatory decision-making based on the scientific evidence.

I hope that these comments have provided some additional insights into the issues. If you would like to discuss the data further, please let me know at your convenience. Also, if you would like to arrange a meeting with DEQ representatives, I would be happy to participate.

Sincerely,



Thomas J. Grizzard, P.E, Ph.D
Professor and Laboratory Director

TJG:mw

Attachment

cc: C.W. Randall

